An Embedded Device Network for Lighting and Building Equipment Control

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Berkeley Lab DER Seminar Series Winter 2002

Conference Room 90-3148, 12-1 unless otherwise noted

	date	speaker	title
1	Tue, 3 Dec.	*Chris Marnay*	Introduction to Distributed Generation and the CERTS Microgrid
2	Thu, 5 Dec.	*Francis Rubinstein*	An Embedded Device Network for Lighting and Building Equipment Control
3	Tue, 10 Dec.	*David Littlejohn*	The Role of Combustion Research in Developing Quality DER Systems
4	Thu,12 Dec.	*Tim Lipman*, CIDER	Vehicles as Mobile Sources of Generation and Ancillary Services
5	Tue, 17 Dec. (Room 90-3075 @ 12:30pm)	*Dimitri Curtil*	DER Simulation by Linking SPARK with EnergyPlus
6	Thu, 19 Dec.	*Hugh Outhred*, U. of N.S.W., Australia	An Australian Perspective on DER

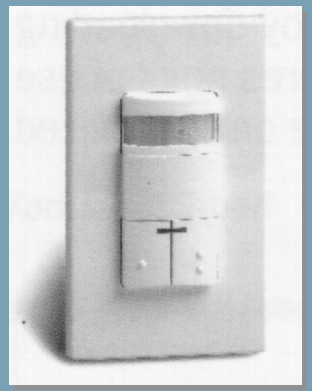
presentations will be posted at der.lbl.gov

Major Points

- ***IBECS is a low-cost infrastructure that connects most building equipment and sensors to the Internet***
- **Adapted *networked, embedded devices* to allow communication/control of building lighting equipment**
- **Extended the network concept to include:**
  - **Controllable envelope equipment (motorized blinds)**
  - **Environmental sensors (temperature, light, occupancy)**
  - **Energy/demand monitoring and submetering**
- ***Future Applications*:**
  - **Integrate total building control (building equipment demand, energy monitoring, etc.) with distributed generation**
  - **Building security and IAQ (environmental sensors, esp. occupancy, temperature, CO_2)**

Lessons Learned from SF Federal Building

- *Occupant sensors* **have proven their cost-effectiveness**
- *Daylighting controls* **can work but are expensive**
- *Integrated controls* **often don't work because of component incompatibility**
- **Occupants like control of their lights**



Problem Statement

- ✓Despite improvements in equipment efficiency, commercial building lighting energy is still squandered
- ✓Simple lighting controls will capture only a fraction of the wasted lighting energy
- ✓Lighting loads remain inelastic
  - ➢Dimming and demand responsive controls needed to increase elasticity
- ✓Occupant benefits of better controls unrealized

Design Requirements for Building Equipment Communications Network

- **Robust control of individual lighting fixtures and switches *(actuators)***
- **Reliable polling of sensors and meters *(sensors)***
- **Provide facilities manager with tools to manage lighting loads with confidence**
- **Allow appropriate control of individual lights by occupants**
- **Backwards compatibility:**
  - **Work with existing lighting equipment**
  - **Work with components from multiple manufacturers**
- **Futureproof:**
  - **Adaptable to current and future communications protocols and standards**

Looked outside lighting industry for a solution:
Embedded Device Networks

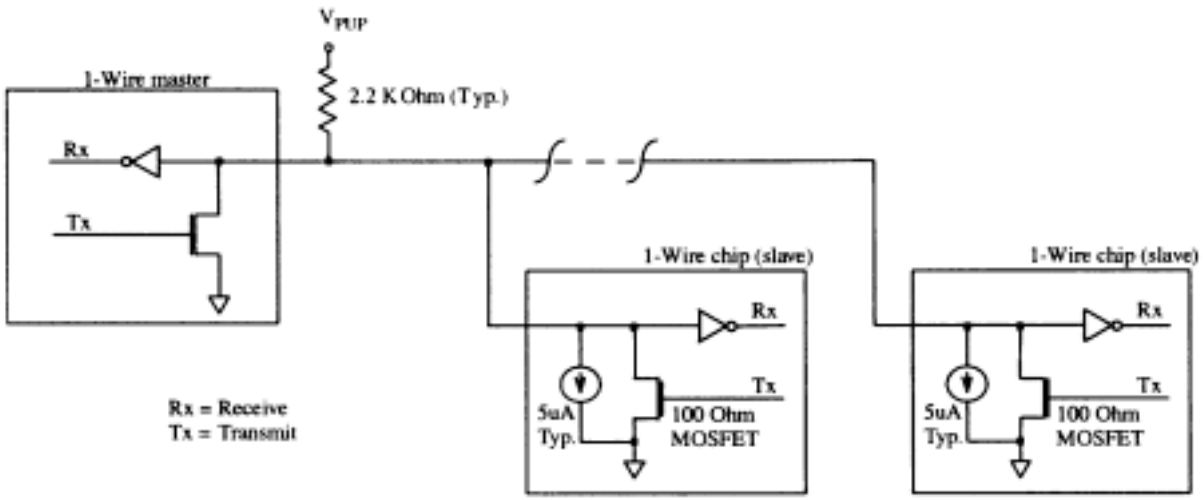
The Search for a Solution

- **Dallas Semiconductor**
  - **Family of low-cost addressable microchips**
  - **1-wire™ communications network**
  - **Initial markets: locks and keys**
- **Sun Microsystems**
  - **Java and Jini**

- ***1 billion light fixtures in US commercial buildings***

The 1-wire™ Network

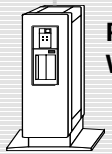
- Serial communication, half duplex, bit sequential
  - Normal speed: 9600 bits/second
  - "Overdrive" mode: 52K and 115K bits/second
- Network (physical layer) is minimally just two wires
- Single master, multiple slave network architecture
  - All network communications initiated by master
  - Slaves steal power from the network



1-wire™ and microLAN are trademarks of Dallas Semiconductor

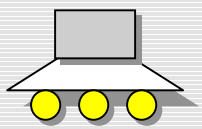
The IBECS System

Ethernet (existing)



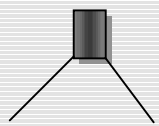
Facility Manager's Workstation

Occupants' Personal Computers



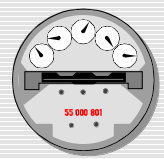
Fixture with dimming ballast

IBECS addressable light switch



Light sensor

Occupant sensor

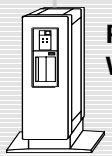


Lighting Power Meter

Lighting Equipment

The IBECS System

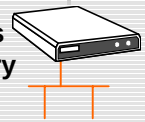
Ethernet (existing)

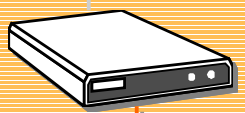


Facility Manager's Workstation

Occupants' Personal Computers

More microLANs as necessary

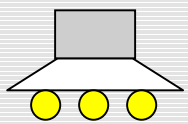




microLAN bridge

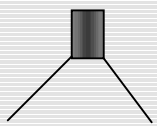
MicroLAN (1,000 linear feet typical with 100 devices)

microLAN

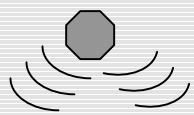


Fixture with dimming ballast

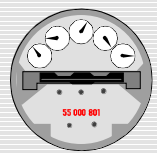
IBECS addressable light switch



Light sensor



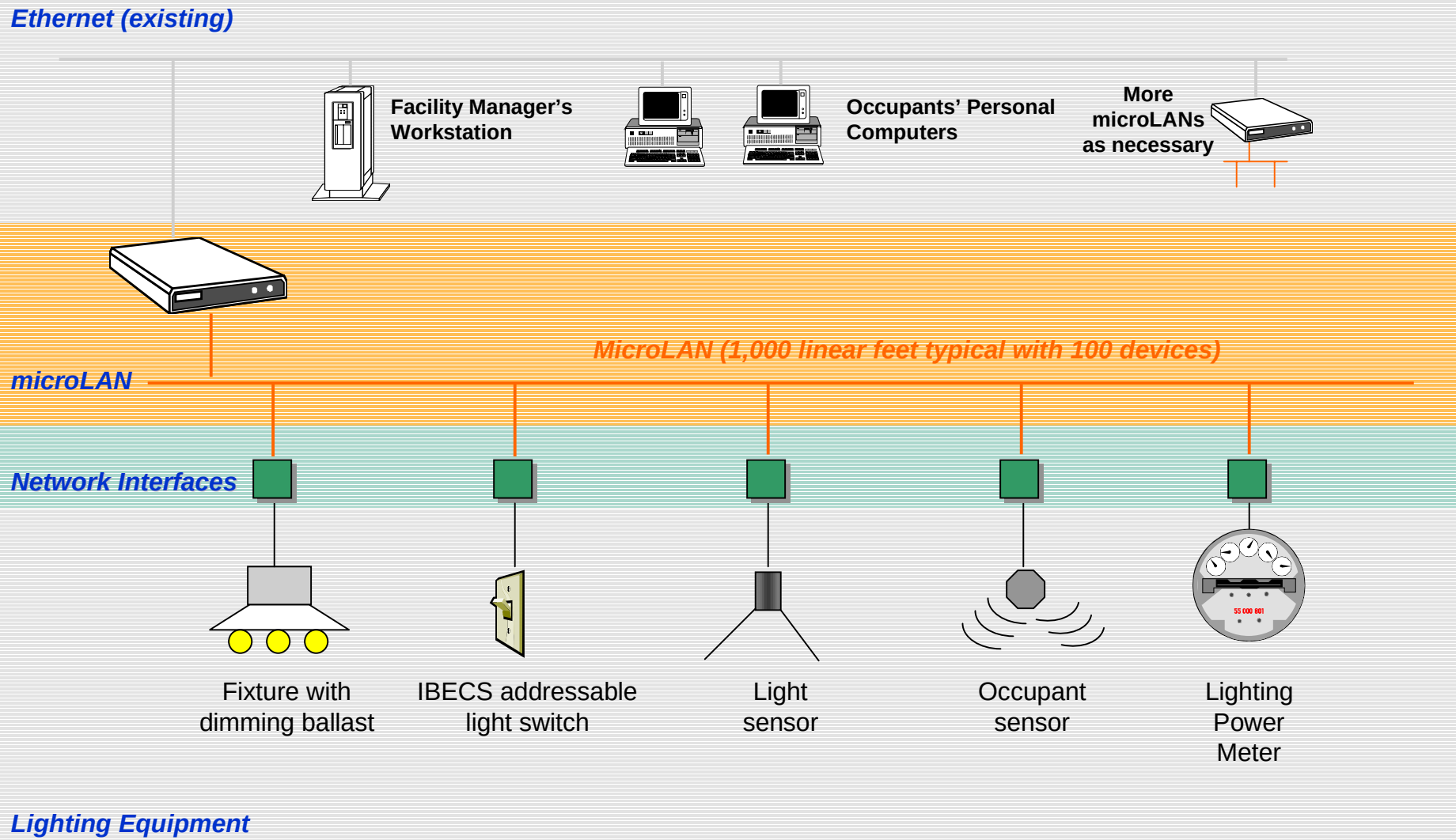
Occupant sensor



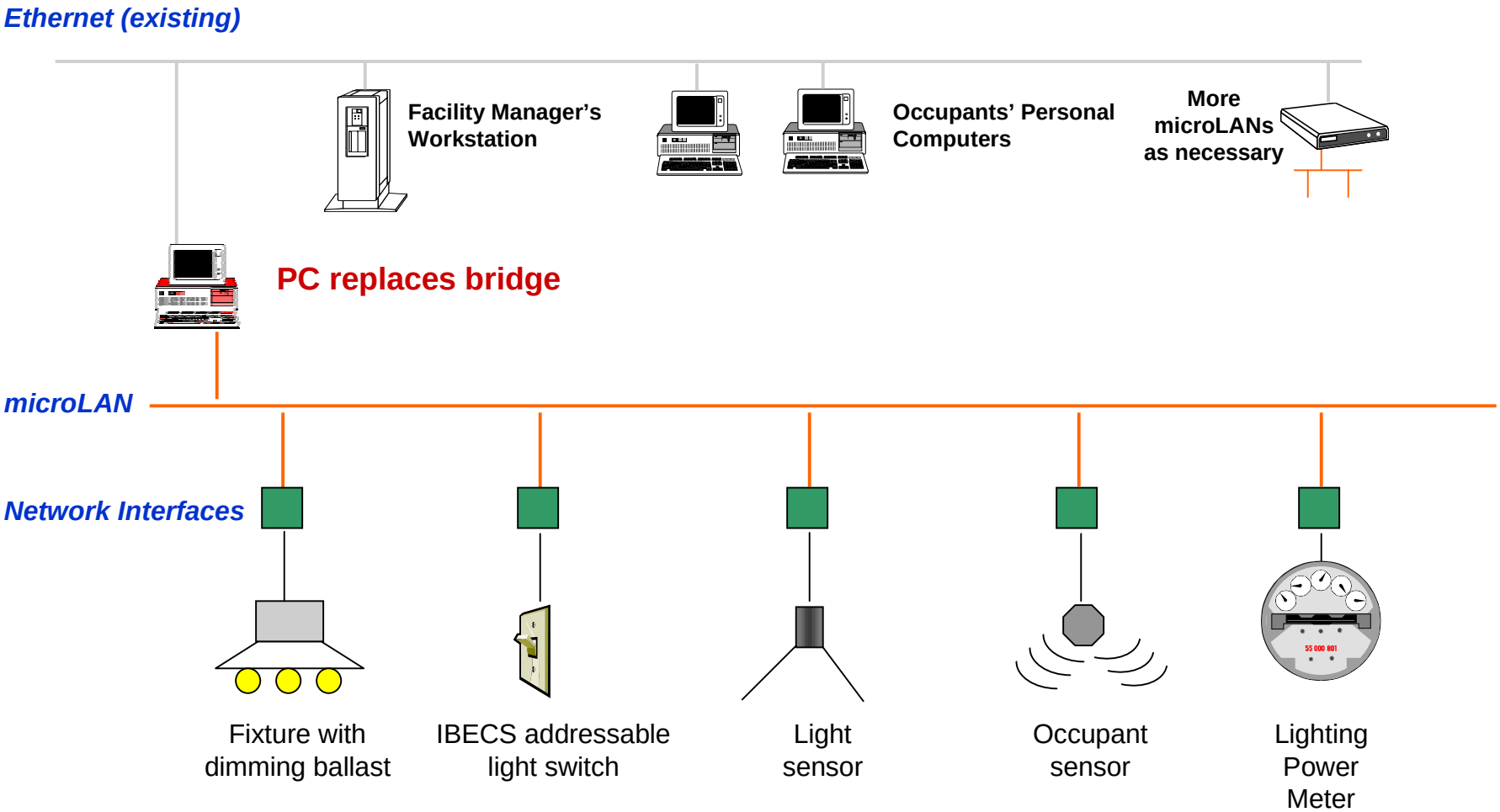
Lighting Power Meter

Lighting Equipment

The IBECS System

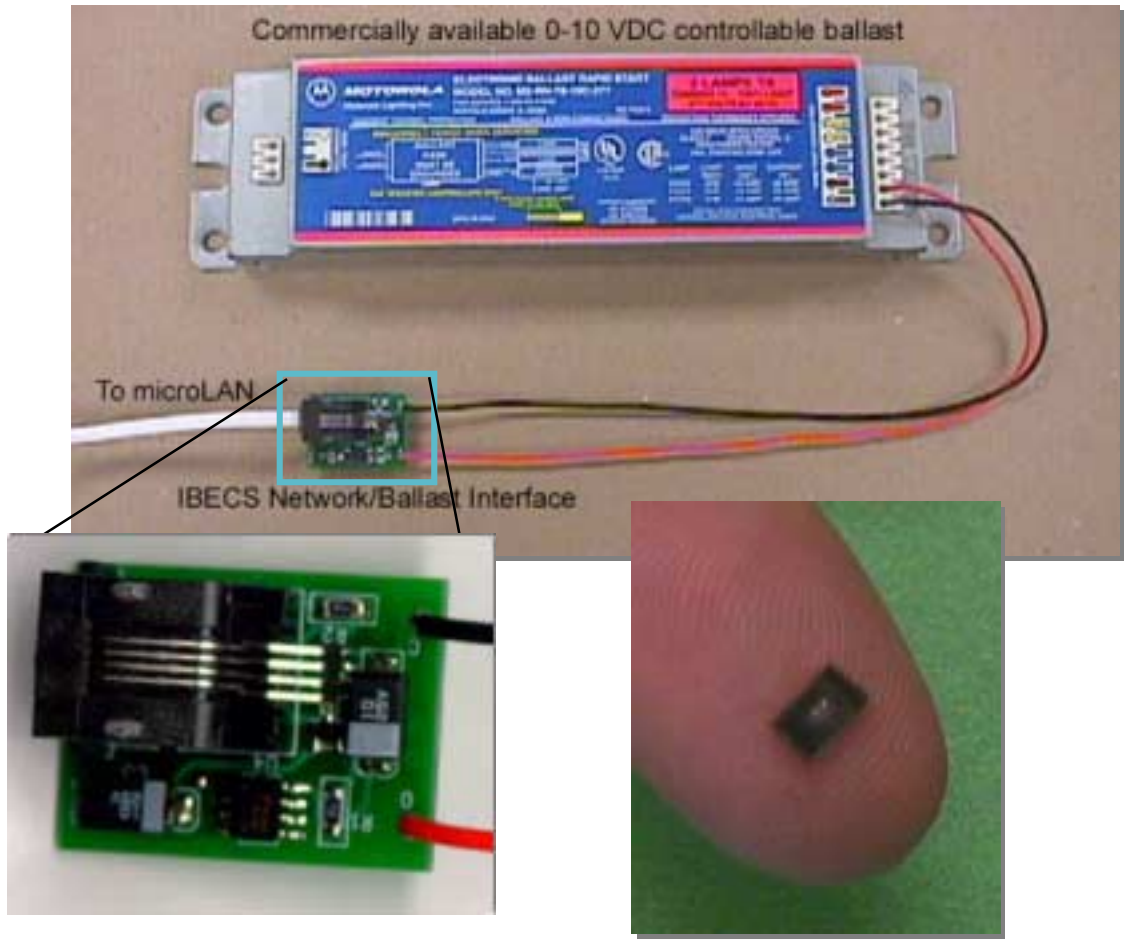


Development System



What's in the IBECS network/ballast interface?

- **Uses specialized microchip: *digital potentiometer DS1820***
- **Each 25¢ microchip has:**
  - **Unique address**
  - **Built-in communication with microLAN**
  - **Ability to perform one "signal transformation"**
- **Interface cost: $1/unit to OEMs**
  - **Less if embedded in ballast**



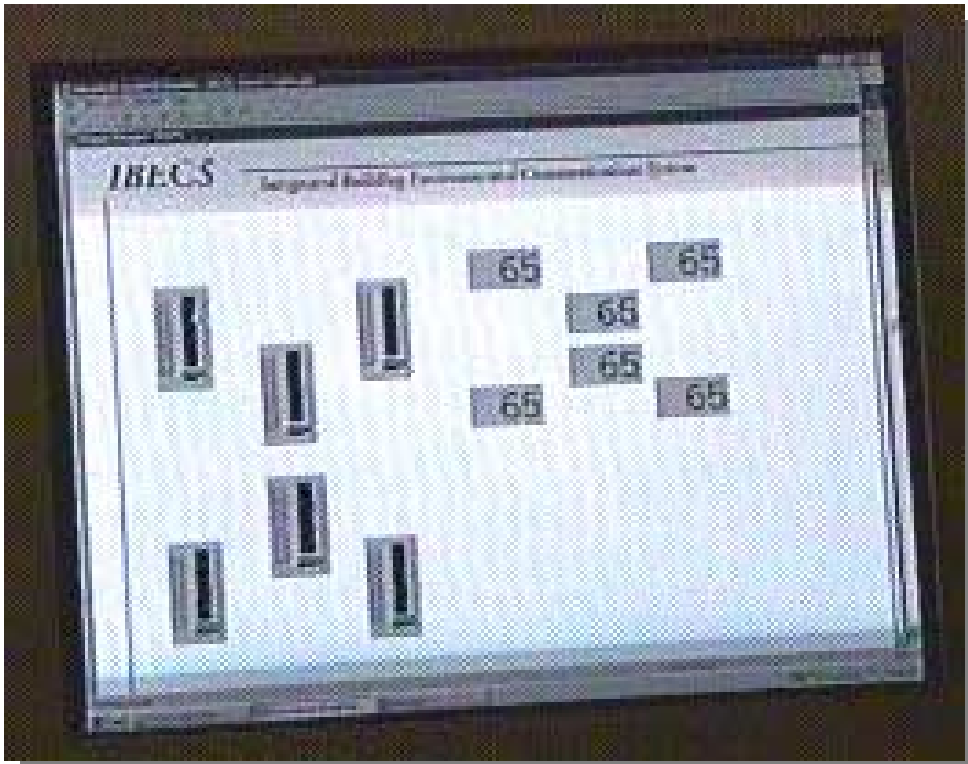
Upper picture shows the IBECS network/ballast interface plugged into an existing controllable ballast. The left inset is a blowup of the interface to show detail. The interface uses the microchip pictured in the right hand inset.

Testing the Network Interface

Office at LBNL where IBECS network/ballast interfaces were tested

Demonstration site consists of four overhead fixtures with six controllable ballasts

Controlling the Network/Ballast Interfaces from the Desktop



Occupant adjusts overhead light level using “control panel” on PC

All Lights On Full
100% Power

Most Lights Dimmed
38% Power

Other completed IBECS Components *

Workspace Environmental Sensor

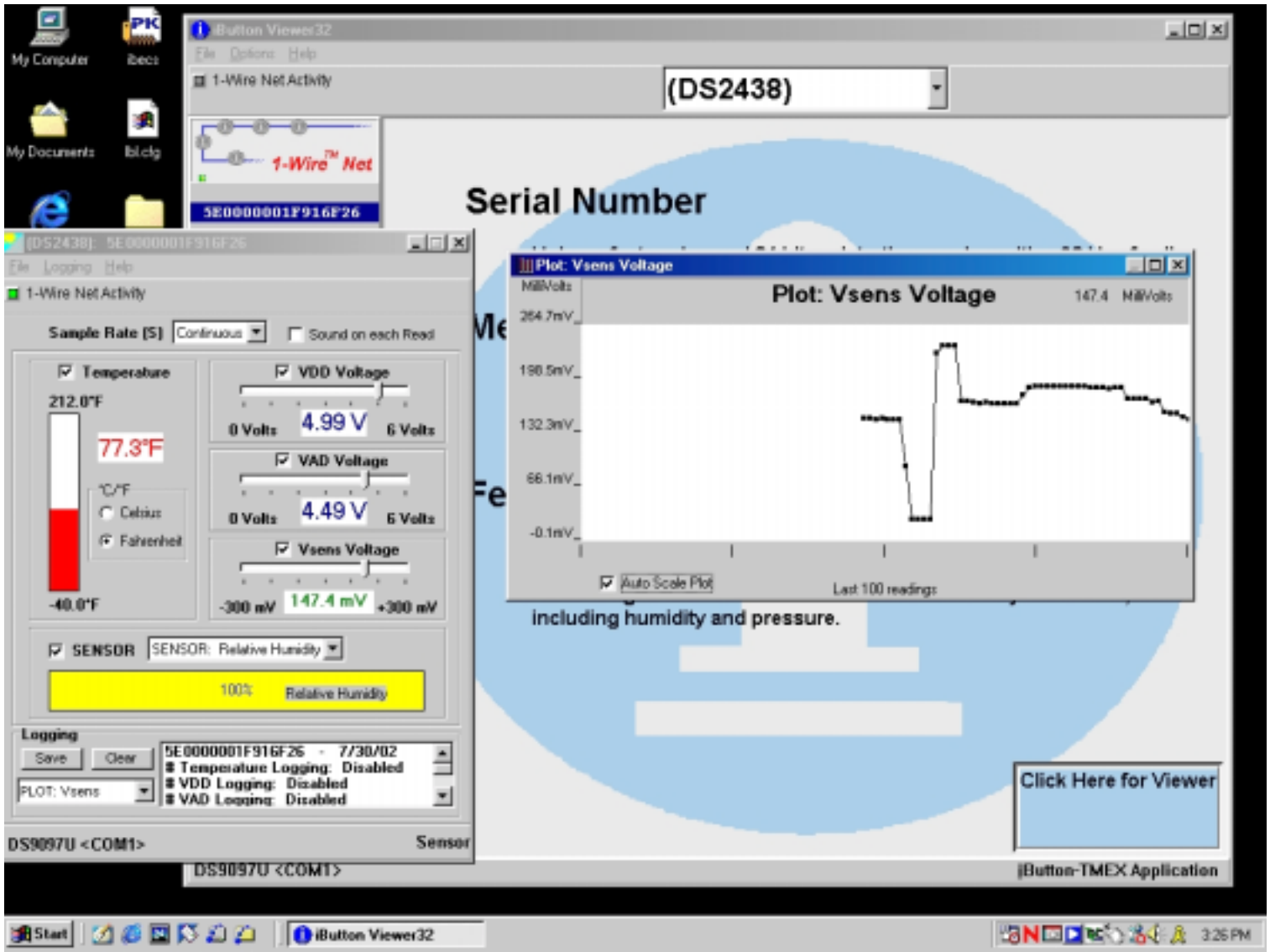
Small Current Monitor

Demand Monitor

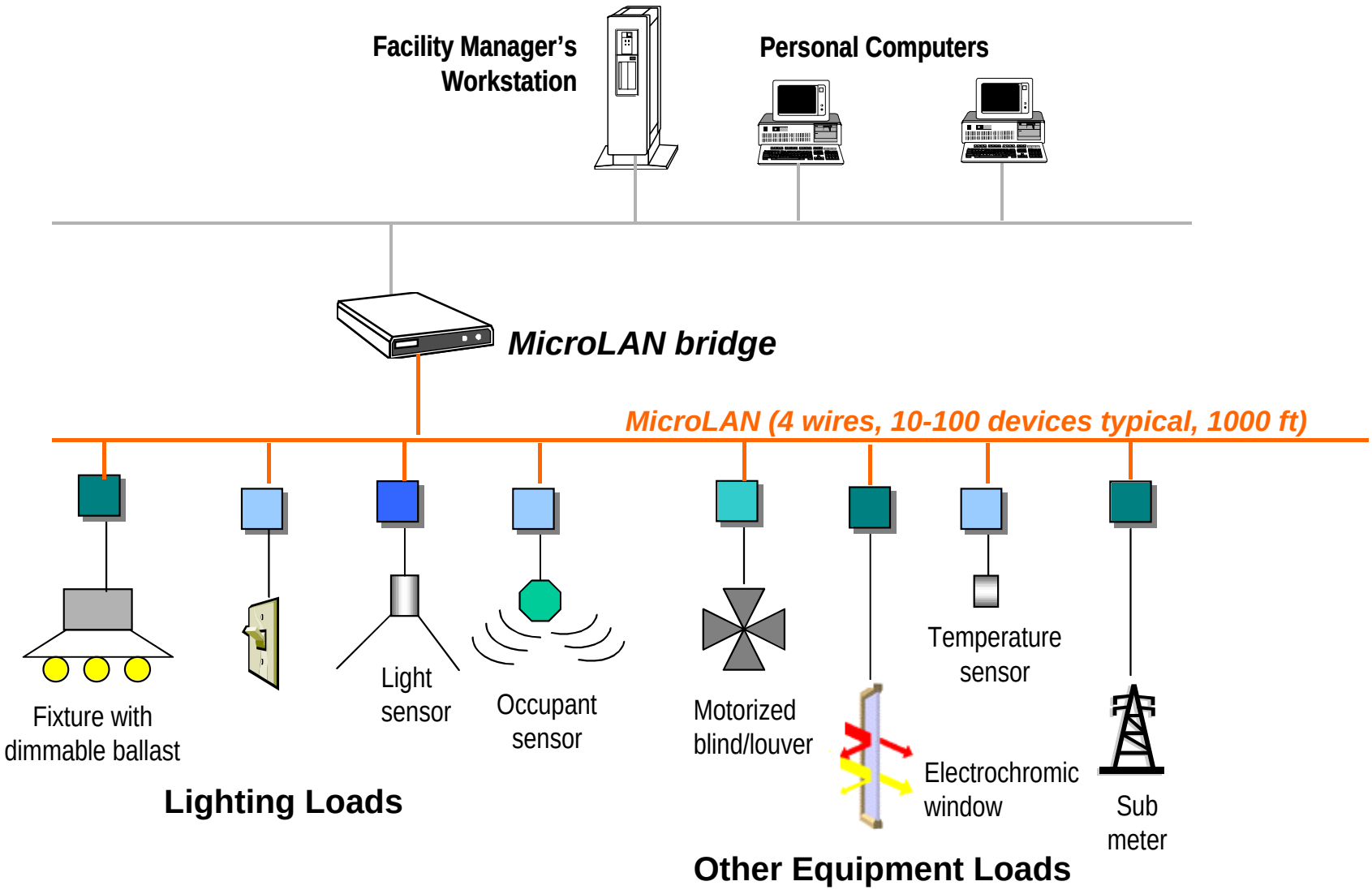
Ceiling Environmental Sensor

*** Co-funded through California Energy Commission PIER Program**

The IBECS environmental sensor as “poor man’s” data acquisition system



Expanding IBECS Beyond Lighting



Automated Venetian Blind Demonstration

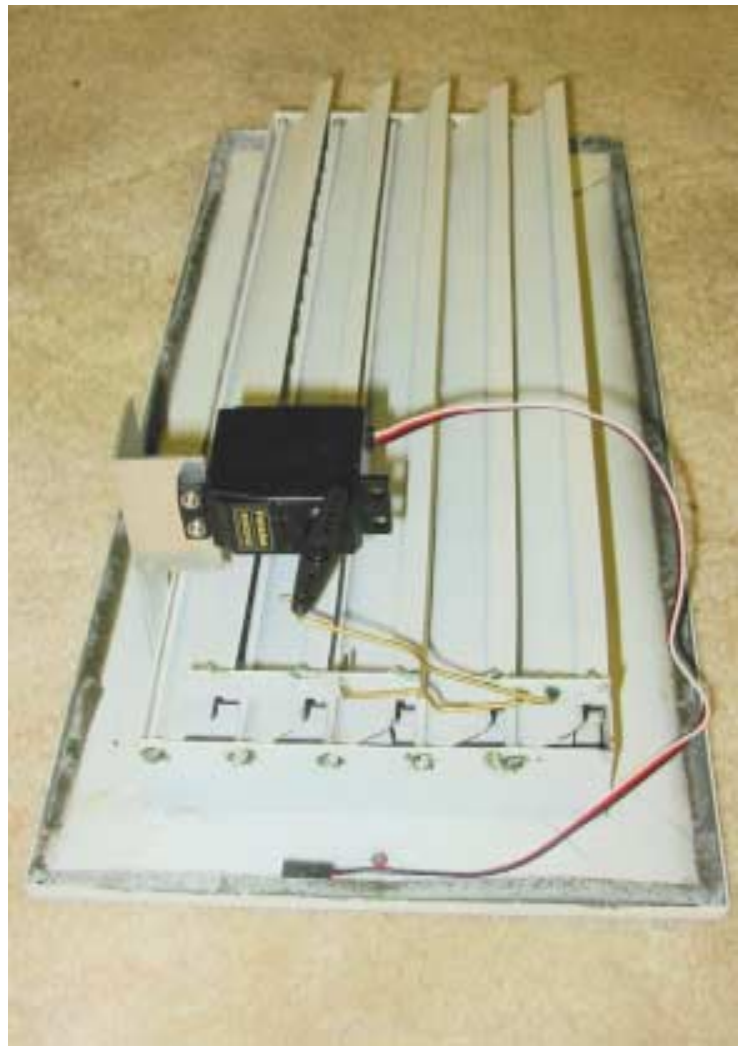
LabView "Virtual Instrument" uses IBECS to control up/down and blind tilt angle of automated venetian blind demonstration at LBNL office

IBECS Research Progress

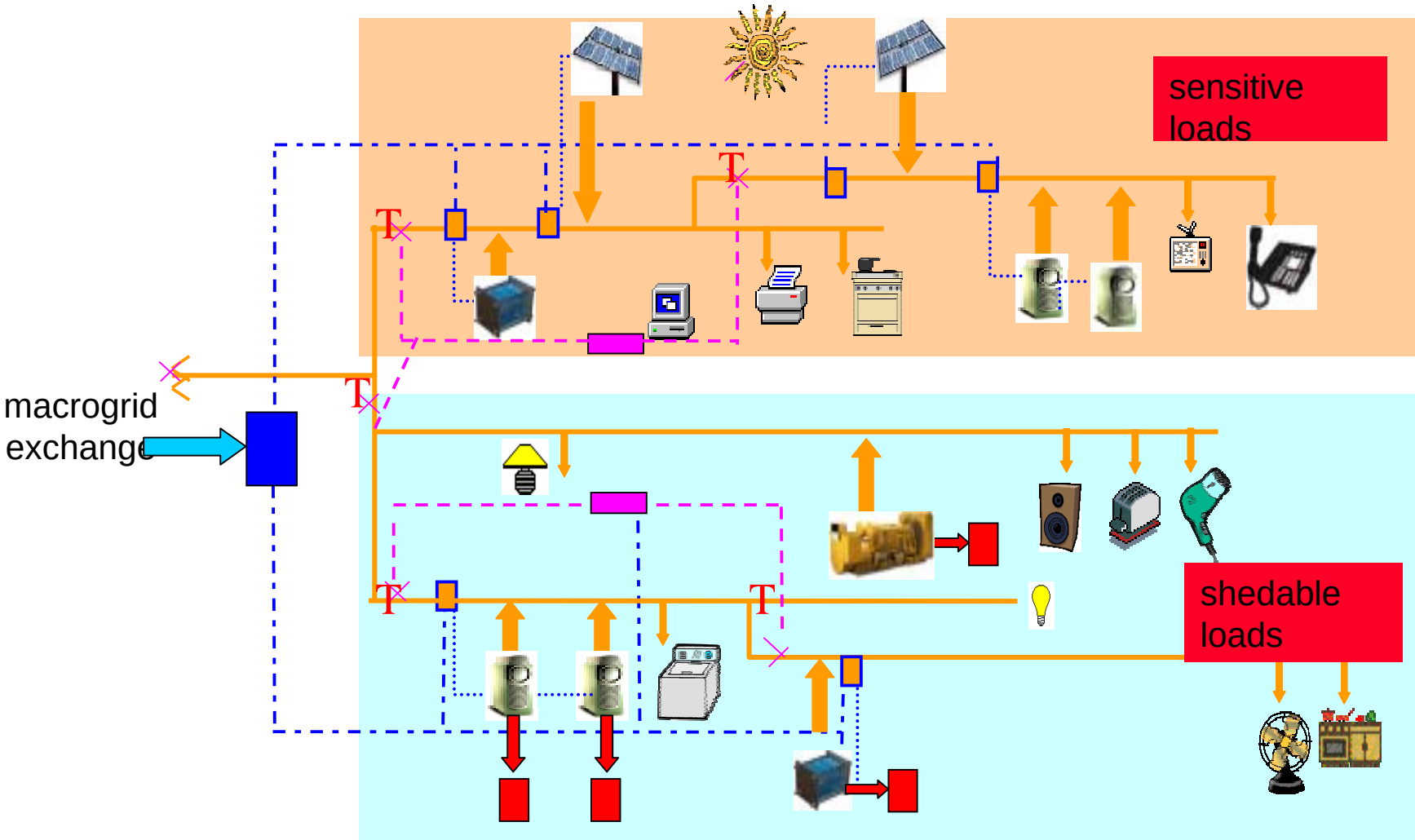
- **Past Accomplishments (2000-2001)**
  - White Paper on IBECS Concept (ACEEE Summer Study 2000)
  - Network/ballast interface
  - Addressable wall switch
- **Current Activities**
  - R&D of additional key IBECS lighting components
    - Environmental sensor, power sensor
  - Select application/platform for developing control software compliant with IEEE P1451Standard on Sensors and Actuators
  - Expansion to wireless and powerline communications, especially for actuators
- **Future Planned Activities**
  - Demonstrations of IBECS in buildings
  - Hardening microLAN for integrated building equipment control
  - Transition to industry

On the Drawing Boards

- **IBECS-controllable HVAC damper**
  - **Estimated Cost: $20/damper**
    - **$10 for servo**
    - **$3 for sensor**
  - **Typically $600**
- **CO_2 sensor**
- **Airflow sensor**



An Example CERTS Microgrid



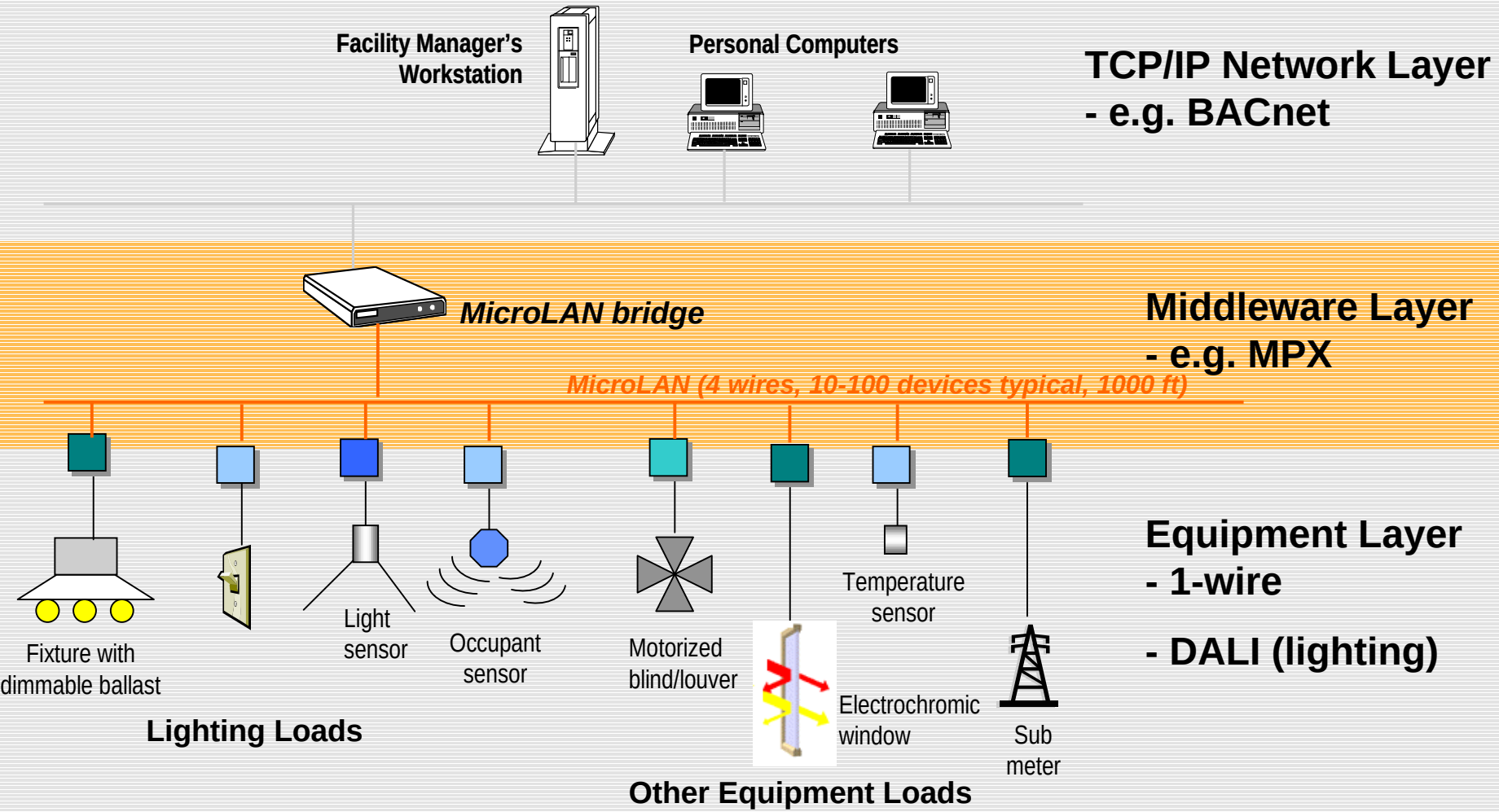
Conclusions

- Networked embedded devices offer least cost path for:
  - Individual fixture control
  - Environmental sensors
- Lighting can draft other building equipment controls (HVAC, envelope, fire & security) into the Era of Networked Embedded Devices
- Watch for emerging standards, especially IEEE Standard P1451 on Sensors and Actuators

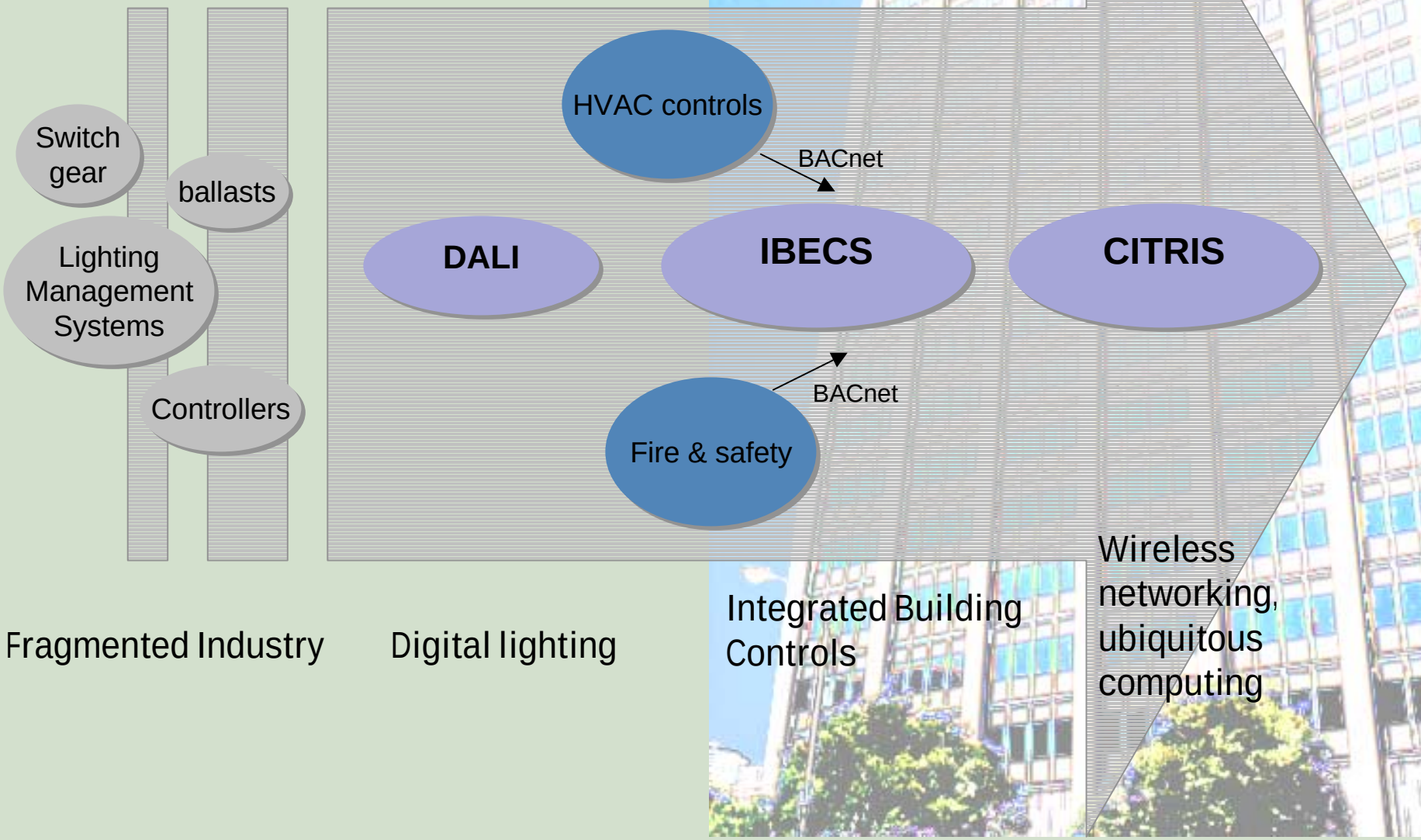
Barriers

- **Economic**
  - Current high cost of dimming ballasts
  - High wiring costs
  - Hidden costs (systems integration and commissioning)
- **Technical**
  - Need proven networking software ("middleware") for building equipment specific applications
- **Institutional**
  - Fragmented state of the lighting controls market
  - Manufacturer cautiousness ("NIH" syndrome)

"Middleware" is a challenge



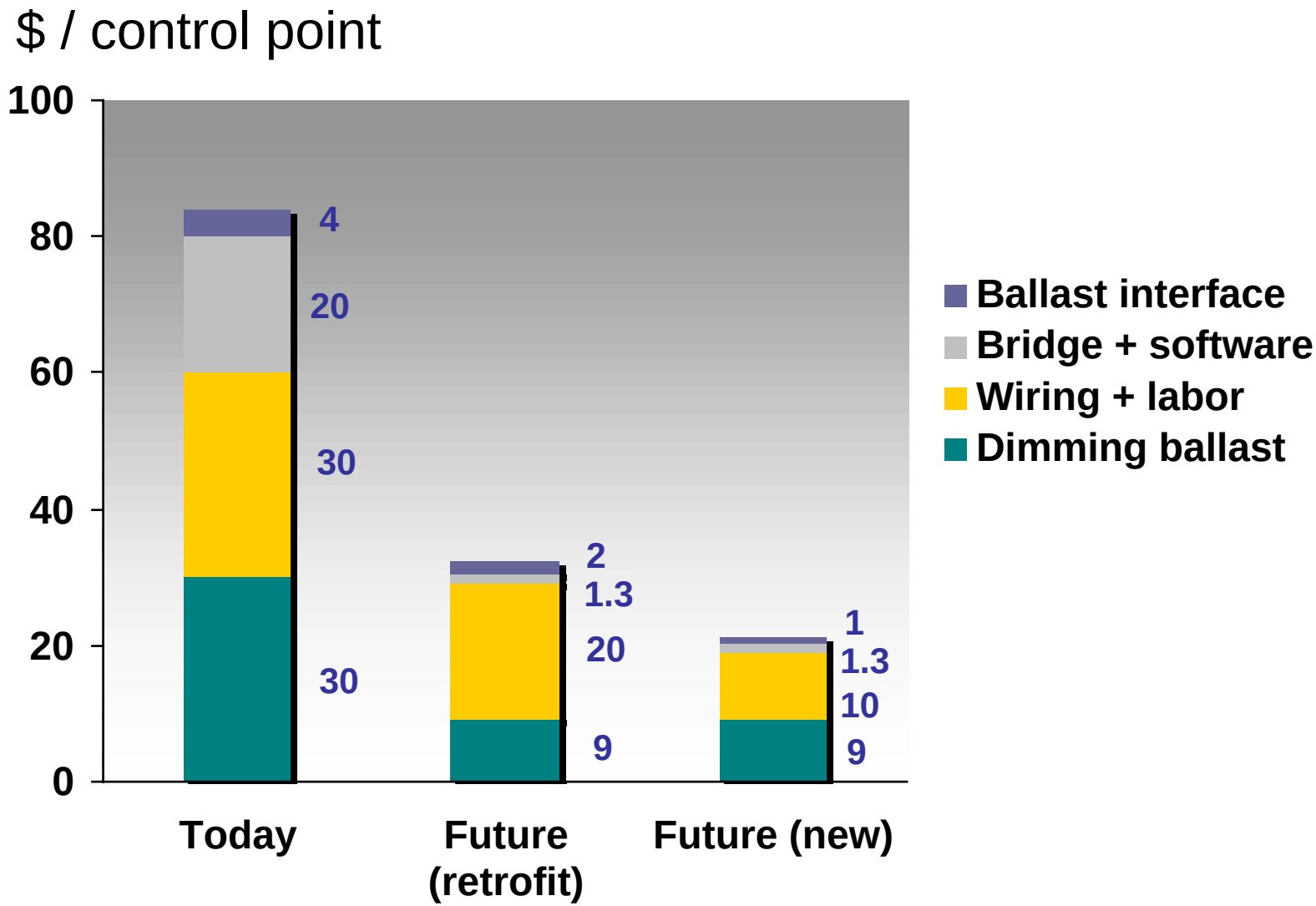
Moving Lighting Controls into the Mainstream



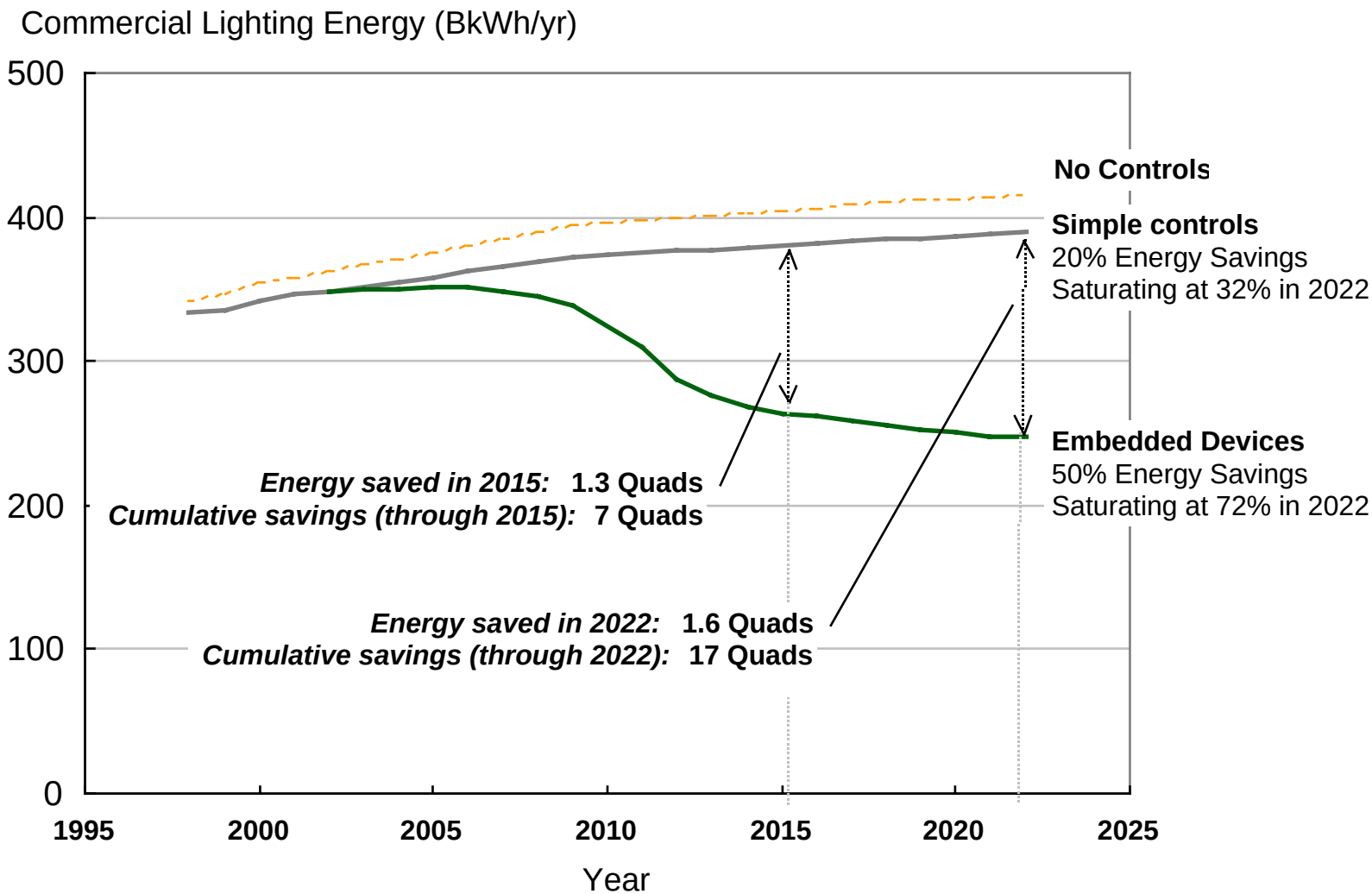
Role for DOE

- **Building industry can't develop a reliable communications and control infrastructure itself**
  - **Lighting and buildings industries fragmented**
  - **Small R&D investment**
  - **Must borrow from electronics and computing industries**
- **DOE investment can accelerate the transfer of communications technologies to building industry**

The Cost of Internet Dimming



Projected Lighting Energy Savings from Networked Embedded Devices



Sources: Department of Energy, Building Technology Office, Core DataBook, 2000
Rabaey, et al, "Smart Energy Distribution and Consupmtion: Information Technology as an Enabling Force, http://www.citris.berkeley.edu/SmartEnergy/SmartEnergy.html